

The Effects of Artificial Sweeteners on Weight Loss and Weight Loss Maintenance in Adults

By
India R. Luetkemeyer, RD

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Science

Chairperson Debra Sullivan PhD, RD

Jeannine Goetz PhD, RD, LD

Lauren Ptomey PhD, RD, LD

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The Thesis Committee for India Luetkemeyer certifies that this is the approved version of the following thesis:

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Chairperson Debra Sullivan PhD, RD

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Abstract

The effects that artificial sweeteners may have on weight have been studied for the past 30 years with conflicting results. Rat studies and prospective cohorts have shown that artificial sweetener consumption may lead to weight gain. On the other hand, randomized controlled trials have suggested the opposite. Because of the conflicting results surrounding this topic, the purpose of the study was to see if artificial sweetener consumption could affect total weight loss and maintenance in adults on a weight loss program. The study also aimed to examine whether or not the type of artificial sweetener consumed had an effect on the amount of total weight loss.

To do this, a secondary analysis of previously collected data from a randomized, clinical trial (Phone versus Clinic; PVC) was done. Participants were grouped by amount of weight lost from baseline to 18 months (<5%, 5-10%, >10%). Total artificial sweetener consumed (in mg) and type of artificial sweetener consumed were compared between the groups using ANOVA and mixed modeling. In a separate analysis, participants were grouped into tertiles based on amount of weight maintained from 6 months to 18 months, and total artificial sweetener consumed (in mg) was compared between the groups.

No significant group ($p = 0.686$), time ($p=0.141$), or group*time interaction ($p=0.267$) regarding total artificial sweetener intake and weight loss over the 18 month study period was observed. When comparing total artificial sweetener intake with weight maintenance, no significant group ($p=0.801$), time ($p=0.148$), or group*time ($p=0.600$) interactions were seen. Therefore, artificial sweetener intake does not appear to affect weight loss or weight maintenance in our population of overweight and obese adults.

These findings are encouraging for those attempting to lose weight. Many people consume artificial sweeteners during weight loss, and the results of this study show that

sweeteners do not prevent weight loss as previously found. Finally, the study is the first to examine the effects of artificial sweeteners in a group that wasn't specifically told to consume or replace foods and beverages with sweeteners. Therefore, it is more generalizable.

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Chapter 1: Introduction

Justification

The effect artificial sweeteners may have on weight has been studied for the past 30 years. In 1988, Rogers et al found that individuals who consumed saccharin-sweetened yogurt one hour before a meal consumed greater amounts of food at that meal (1). These results suggested that despite artificially sweetened foods having no calories, they may lead consumers to eat more and therefore lead to weight gain. Since these findings, a number of further studies, including rats as well as humans, have found conflicting results.

The studies done on rats have been consistent with the findings of Rogers et al (1). When given artificial sweeteners before meals or with meals ad libitum throughout the day, rats consumed a greater amount of calories (2-4) and gained more weight (2-5) than those who were only given access to standard chow. These results held true regardless of the duration, type of sweetener, or amount of sweetener used. Although these results cast insight into the effects artificial sweeteners may have on weight, in order to generalize results in humans, human studies have been done.

Human prospective cohorts also showed an association between artificial sweeteners and subsequent weight gain. Three studies looked at the change in Body Mass Index (BMI) and waist circumference from baseline to multiple follow-ups in groups of individuals who consumed artificially-sweetened beverages vs. groups who did not. The change in BMI was greater (6, 7) as well as the waist-circumference (8) in those who consumed artificially sweetened-beverages. Although these trends indicate a positive relationship between artificial sweeteners and weight gain, epidemiological data cannot prove cause and effect.

Numerous randomized controlled trials, including both long-term and short-term, have found opposite results. Short-term studies found that artificial sweeteners, when consumed in

fixed amounts (9-12) or ad libitum (13) did not lead to increased caloric consumption at the subsequent meal. This held true whether the artificial sweetener was consumed in beverages (9, 10, 12, 13) or foods (11).

Long-term randomized controlled trials have looked at a wide array of circumstances regarding artificial sweeteners and weight as well. Regardless of whether artificial sweeteners were added to the diet of individuals with no other dietary changes (14-17), or if sugar-sweetened foods and beverages were replaced with artificially-sweetened foods and beverages (18), there appears to be a correlation. Those who added or replaced the foods and beverages with artificially-sweetened foods and beverages lost more weight than those who did not. In fact, in one study, greater consumption of artificial sweeteners was correlated with greater weight loss, indicating that there may be a dosage relationship (16).

The results regarding artificial sweeteners and weight held true whether or not the participants were free-living or on a weight-loss regimen. In two of the studies done during weight-loss (16, 19), those who were encouraged to consume the artificially-sweetened products had less total weight regain than those not consuming artificial sweeteners. This suggests that artificial sweeteners may also aid in weight maintenance.

These two studies, by Blackburn et al. and Peters et al, are the only studies identified that specifically evaluated the effects artificial sweeteners may have on weight maintenance following a weight loss period in adults. Blackburn et al. (16) only looked at the effects of aspartame, and therefore, the results cannot be generalized to the other artificial sweeteners. Although Peters et al. (19) did look at all artificial sweeteners, the participants in the control group were encouraged to consume water instead of artificially-sweetened beverages. If these participants already regularly consumed artificially-sweetened beverages, the change to water

only could have been a greater behavioral change than the intervention group, who were encouraged to continue artificial sweetener use, which could have potentially affected the results. Therefore, it is of interest to study the effects all artificial sweeteners may have on those undergoing a weight-loss regimen without the additional behavioral change requirements.

Statement of Purpose

More than two-thirds of the US population is now overweight or obese, and this number is only increasing (20). Several studies have found that artificial sweeteners may aid in weight loss (14-18). Only two studies (16, 19), one of which was published in 1997 and therefore may no longer be generalizable (16), have looked at the effects artificial sweeteners have during weight loss and maintenance in individuals on a weight-loss regimen. Furthermore, the weight maintenance phase of a weight-loss program is arguably a longer portion of a person's life, and can be the deciding factor on whether or not the weight is kept off. Therefore, the purpose of this thesis was to evaluate the effects that artificial sweeteners have on weight loss and maintenance in adults throughout the duration of a weight loss program.

Research Questions

- 1.) In a group of individuals on a weight-loss and maintenance regimen, does the consumption of artificially-sweetened foods and beverages have an effect on the amount of total weight lost over 18 months?
- 2.) In a group of individuals on a weight-loss and maintenance regimen, does the type of artificial sweetener consumed (aspartame, sucralose, acesulfame-K, or saccharin) have an effect on the amount of total weight lost over 18 months?

3.) In a group of individuals on a weight-loss and maintenance regimen, does the consumption of artificially-sweetened foods and beverages have an effect on the amount of weight loss maintained during 12 months of a maintenance period?

Chapter 2: Literature Review

I. Introduction

More than two-thirds of the US population is now overweight or obese, and this number is only increasing (20). The high prevalence is concerning, considering obesity is associated with life-altering diseases such as type 2 diabetes (21), stroke (22), hypertension (23), and some cancers (24). While the exact cause of obesity cannot be pinpointed as it is related to many factors including genetics (25) and family history (26), the recent increase in obesity requires the need to look into changes in lifestyle that may have an effect.

As obesity has risen, so has sugar intake. Sugar consumption in the US has increased 20% in the past 30 years, suggesting that sugar-sweetened foods and beverages may be a contributor to the obesity epidemic (11). Indeed, added sugar intake can lead to higher daily energy intakes, fat deposition, and weight gain (11, 14). Because of the effect that sugar has on weight and subsequently other preventable diseases, the 2015-2020 Dietary Guidelines for Americans suggests to consume no more than 10% of calories per day from added sugars (27).

In an attempt to limit sugar intake, individuals are seeking alternatives to sugar-sweetened beverages and sugar-dense foods (6). Because of this, nonnutritive sweetener consumption in the US has increased in recent decades, from 3.3% of the population in 1965 to about 15% of the population currently (28). Food and beverage companies have capitalized on this increased intake of artificial sweeteners. They are found in a wide variety of foods, especially those labeled as “sugar-free,” “lite,” or “diet,” including sodas, gums, baked goods, puddings, ice creams, syrups, and candies (29). Exact data on the amounts of artificial sweeteners in products are limited (28). However, in general, a 12 ounce can of diet coke contains about 192 milligrams of aspartame (30).

Aspartame is one of five nonnutritive sweeteners, also called artificial sweeteners, approved by the US Food and Drug Administration (FDA): saccharin, aspartame, sucralose, neotame, and acesulfame-k (28) . These sweeteners are abundantly sweeter than sugar, and therefore consumers need much less to reach the desired sweetness (31). Additionally, most sweeteners excluding aspartame (which can be metabolized at 4 kcal/g) are excreted, unmetabolized (31). As a result, they are either very low in or void of calories. Since these sweeteners satisfy the sweet flavor in foods and beverages without the calories, they may be a replacement for sugar.

However, in 1988, Rogers et al. discovered that individuals who consumed saccharin-sweetened yogurt one hour before a meal consumed greater amounts of food at the meal (1). These results suggested that artificial sweeteners, although low or void in calories, may actually cause individuals to consume more calories. If true, these sweeteners may lead to greater total energy intake as well as increased weight. Therefore, the purpose of the literature review was to determine if the consumption of artificial sweeteners is related to weight gain in adults.

II. Randomized Controlled Trials

The randomized controlled trial is considered the golden standard of research (32). Therefore, the majority of the research in the last 25 years relating to artificial sweeteners and weight gain is randomized controlled trials, including both human (6-11, 13-18) and rat studies (2-4). Because they are experimental, an intervention was applied to the subjects and outcomes were measured based on these interventions. For the studies on this topic, the intervention was varying doses of artificial sweeteners, and the outcomes were energy intake, body weight, or both. The studies looked at both short-term and long-term effects of artificial sweeteners.

A. Rat Studies

Most of the rat studies done regarding artificial sweeteners and weight gain have a very similar design. The rats, of different breeds and genders, were fed varying amounts of artificial sweeteners and then given food (chow) to eat ad libitum. The subsequent intake and body weight were measured and compared to baseline. By this design, several rat studies showed similar results (2-4).

1. Sweeteners and Food Given Together

In three different studies, male and female rats were given 20 ml (2, 5) or 30 ml (3) of yogurt either sweetened with 0.3% saccharin (2, 3, 5), 0.4% aspartame (2), 0.3% acesulfame K (3) or 20% sucrose (2) or glucose (3). The rats had access to these yogurts at the same time as standard chow, which they could consume ad libitum, for the duration of the 14 day (3, 5) and 12 week (2) studies. Despite the fact that the groups receiving saccharin-, aspartame-, and acesulfame K-sweetened yogurts received fewer calories from the yogurts, the total daily intake throughout the study were significantly higher than the sucrose group (2). These results suggest that the lack of calories from the yogurt caused them to overcompensate and consume more from the chow. As a result, the rats subsequently gained significantly more weight throughout the study (2, 3).

In another study of similar design (5), male rats were given 20 ml of yogurt either sweetened with 0.3% saccharin or unsweetened. These rats were given access to these yogurts as well as standard chow, which they consumed ad libitum for 14 days. The rats in the saccharin-sweetened yogurt group gained more weight than those in the non-sweetened yogurt group despite no difference in total caloric consumption between the groups. Although the rationale

behind this is unknown, it is postulated that saccharin may lead to a down-regulation of energy expenditure from digestion.

2. Sweeteners and Food Given Separately

When given constant access to artificially-sweetened foods throughout the day as well as ad libitum access to standard chow, rats consumed more chow and gained more weight (2, 3) than when given a control. Similar results occurred when male and female rats were given 20 ml of yogurt sweetened with 0.3% saccharin, 0.3% acesulfame K, or 20% glucose for only an hour a day, and later given access to chow ad libitum for 14 days (3). Although the actual intake from chow was not recorded in the study, the intake of the sweetened yogurt was. The rats in the glucose-sweetened yogurt group gained significantly less weight than the rats in the artificially-sweetened yogurt group, despite the glucose-sweetened yogurt group consuming more calories from the yogurt. The fact that the weight gain did not differ between the two types of artificial sweeteners suggests that the different types of artificial sweeteners may affect body weight similarly. Therefore, weight gain may occur regardless of the type of artificial sweetener or whether or not the artificial sweetener is given with meals (2, 3) or before meals (3).

3. Sweeteners and the Obesity Prone

Some humans are more prone to becoming overweight or obese, and these individuals may respond differently to obesogenic environments than the general population (4). Therefore, rat studies have been conducted to specifically examine how overweight- and obesity-prone rats react to artificial sweetener supplementation. Swithers et al. (4) gave male and female rats a diet high in fat, energy, and sugar for twelve days prior to the study. These rats were then separated into two groups based on how much weight was gained: those who were prone to gaining weight were deemed diet-induced obese (DIO) and those who were not were considered diet resistant

(DR). Each group was subsequently given ad libitum access to standard chow along with 30 g of yogurt over 4 weeks. For 2 of the weeks, the yogurt was unsweetened, and for the other 2 weeks, it was sweetened with either 0.3% saccharin or 20% glucose.

The weight of the rats in the DIO group was affected by the type of sweetener used. Those who received saccharin-sweetened yogurt gained significantly more weight than those who received the sucrose-sweetened yogurt, despite the sucrose-sweetened yogurt containing more calories (4). On the other hand, the rats in the DR group gained the same amount of weight regardless of whether they received saccharin or sucrose-sweetened yogurt. In conclusion, those prone to gaining weight may be affected the greatest from artificial sweeteners.

B. Human Studies

The evidence from the rat studies suggests that artificial sweetener supplementation may lead to subsequent increased energy intake, resulting in weight gain (2-5). These studies are beneficial in many cases, as conditions can be much more controlled than in human studies. For example, one of the rat studies (2) controlled for physical activity by confining the rats. This would not be possible in a human study. However, it is important to note that the results found in the rat studies cannot be extrapolated to humans (4), and therefore human studies must be done as well.

1. Short-term Studies

Both short-term and long-term studies have been conducted in humans regarding artificial sweeteners and weight gain. Short-term studies focus on whether or not the consumption of artificial sweeteners before a meal leads to a subsequent increase in energy intake during meals. Two studies focusing on aspartame specifically (9, 13) gave subjects

flavored water either by itself, sweetened with fructose or glucose, or sweetened with aspartame. Another study, by Holt et al, examined diet cola, regular cola, and plain carbonated water (12).

i. Artificial Sweetener Preloads in Beverages

In two of the studies, the preloads were given in fixed amounts. Rodin supplemented participants with 0.25 g of aspartame or 50g fructose or sucrose per preload (9), and Holt served preloads of 375 mL of either diet cola, regular cola, or water. In the other study, the subjects were allowed to consume the sweetened beverages ad libitum (13). Therefore, the total amount of aspartame varied depending on the individual. Despite the differences in beverage distribution, energy intake directly after the preload (9, 12, 13), for the remainder of the day (12), and the next day (13) did not significantly differ between any of the preloads in any of the studies, when not taking into account the calories from the sugar-sweetened beverages.

Another study of similar design (10) found the same results. Van Wymelbeke et al. studied the short-term effects of multiple, unspecified artificial sweeteners on intake. Intake of one day was measured after subjects drank 2 liters of water throughout the day sweetened with either sucrose or intense sweeteners. The beverages were then consumed in alternating order each day for a month to habituate the participants to the beverages. Intake of one day was again measured after subjects drank 2 liters of water throughout the day sweetened with either sucrose or intense sweeteners. Energy intake, without the calories from the beverages, did not differ between groups.

The results of these three preload studies suggest that artificial sweeteners in beverages, when given in fixed (9, 12) and varying amounts (13) may not subsequently lead individuals to consume more at subsequent meals. This may hold true whether or not individuals have repeated exposure to artificial sweeteners (10), such as those who consume diet beverages regularly.

These findings contrast to those done on rats, which suggested that repeated exposure does cause subsequent increased intake and weight gain (2-5). However, since the rat studies involved yogurt instead of beverages, human studies using foods sweetened with artificial sweeteners should be analyzed.

ii. Artificial Sweetener Preloads in Foods

Artificial sweeteners, when consumed within foods, may not lead to short-term increases in energy intake. A study done by Anton, et al (11) compared energy intake over 3 days in a group of subjects who consumed unspecified preloads of aspartame and stevia given in crackers and cream cheese versus preloads of sugar given in these foods. The preloads were given to the subjects before lunch and dinner; afterwards, they were presented with a buffet style meal. The study found that there were no differences in subsequent energy intake throughout any of the three days. This shows that although the subjects consumed fewer calories in the preload sweetened with aspartame or stevia, they did not subconsciously compensate for lack of calories in their subsequent meal. These results further back-up the other preload studies and call into question the results of the rat studies.

2. Long-term Studies

Short-term studies are an indicator of how artificial sweeteners may affect one meal. However, body weight is an outcome of long-term energy deficit or excess (20), and cannot be studied directly in short-term studies. Considering weight can be lost or gained at a safe rate of 1-1.5 pounds per week (20), it is necessary to study the effects that artificial sweeteners may have on energy intake and body weight in periods longer than this time frame.

i. Adding Artificial Sweeteners to the Diet

a. Free-Living Individuals

Researchers have explored how energy intake and weight gain are affected when foods and beverages made with artificial sweeteners are added to the diet of free-living individuals. By this method, Raben et al (14) supplemented overweight individuals with varying degrees of unspecified artificial sweeteners over 10 weeks. Subjects received artificially sweetened products, such as yogurt, marmalade, and ice cream. Participants were instructed to consume a specific amount of these foods per day as well as to not change anything else about their lifestyles, which was verified by a questionnaire. A group of participants supplemented with sucrose-sweetened foods and beverages served as a control.

Not all foods and beverages sweetened with artificial sweeteners were calorie-free. Therefore, it was possible that the addition of these foods and beverages to the diet could have led to an increased daily energy. Despite this possibility, the subject's total energy intake non-significantly decreased (14) compared to baseline. Although the decrease in energy intake was insignificant, there was still a significant decrease in body weight and fat mass when compared to baseline, suggesting that the decrease in energy was adequate to produce such effects.

Similarly, in another long-term study of free-living individuals done by Tordoff et al. (15), each subject consumed, in counterbalanced order, four 10-ounce bottles of sugar-sweetened soda, four 10-ounce bottles of aspartame-sweetened soda, or no soda in three different periods for 9 weeks total. Over the duration of the study, subject's intakes during the aspartame-sweetened beverage period decreased by 179 kcal/day when compared to the no soda period. Weight decreased significantly in males (-0.47 kg, $p < 0.05$) and increased slightly, but non-significantly, in females (+0.25, $p\text{-value} > 0.05$), leading to an overall non-significant decrease in

weight. Furthermore, the total daily sugar intake decreased throughout the study when compared to the no-soda period, suggesting that the low-energy artificially-sweetened beverages replaced high-energy density products (14).

The results of Raben et al. (14) and Tordoff et al.(15) suggest that simply adding artificially-sweetened foods and beverages to the diet may lead to decreased energy intake and weight loss (14, 15). Although the exact mechanism is unclear, it appears that replacement of sugar-sweetened products with artificially-sweetened products may result in fewer total calories consumed and aid in weight loss.

b. Individuals on Weight-loss Regimen

To test this theory, long-term studies have also been done on subjects who are put on a weight-loss program (16, 17, 19). Participants who were encouraged to consume aspartame-sweetened products lost equal amounts of weight over 16 weeks as those who were discouraged the use of artificially sweetened products (16). Similarly, participants who were encouraged to consume artificially sweetened foods and beverages, not just those sweetened with aspartame specifically, lost more weight over 12 weeks than those who were discouraged their use and asked to consume only water instead (17, 19).

These results suggest that aspartame does not hinder weight loss and may aid in weight loss efforts. In fact, the subjects who lost and maintained the most weight consumed the highest amount of artificial sweeteners (16), suggesting that there may be a dosage relationship. Furthermore, artificially sweetened beverages may be associated with greater weight maintenance (16, 19). The subjects who were encouraged to consume the artificially-sweetened beverages had less total weight regain after a one-year maintenance phase than those not consuming artificial sweeteners.

It is of interest to study whether or not adherence to the diet affected the results of the weight-loss studies. For example, because neither of the studies recruited individuals with a specific previous artificial sweetener intake (16, 17), it is possible that the subjects could have been consuming them regularly prior to the intervention. If this were the case, it would have been a greater behavioral change for those in the group that were discouraged from using sweeteners, which could have potentially affected the results. Therefore, it is of interest to study the effects artificial sweeteners may have on those undergoing a weight-loss regimen without the additional behavioral changes requirements.

ii. Replacing Sugar-sweetened Beverages with Artificially-Sweetened Beverages

One study specifically looked into the effects that adherence to the diet may have on intake and body weight (18). However, in this study, instead of adding artificial sweeteners to the diet, participants were randomized to replace at least two 200-calorie servings of sugar-sweetened beverages (sodas, sugar-sweetened fruit juices, etc.) with either water or diet beverages (beverages sweetened with artificial sweeteners). Both of the experimental groups were required to attend monthly behavioral counseling sessions to increase adherence to their respective diet replacements. The dietary intake and weight of both of these groups over 6 months were then compared to a group in which only behavioral counseling occurred.

These individuals were given general weight loss tips (decreasing portion sizes, increasing vegetables, increasing physical activity), but were never specifically given weight loss goals or put on a calorie-restricted diet (18). All three groups lost significant amounts of weight and had significant decreases in total energy at both 3 months and 6 months. However, the diet beverage group had a greater chance of losing 5% of their body weight than the control group.

This study suggests that weight loss is achievable using artificial sweeteners with behavioral counseling as well.

On the other hand, another study (33), which looked at the effects of replacing sugar-containing foods with reduced sugar foods without the behavioral counseling, found different results. Energy intake and body weight of participants who were instructed to replace traditional sugar-containing foods with reduced sugar alternatives (which contained artificial sweeteners) over 10 weeks were not significantly different from the control, which included participants who continued their habitual diet for the 10 week intervention. However, this likely was attributed to the fact that unlike diet beverages, reduced sugar foods may still contain calories, leading to little or no change in energy intake and subsequent weight.

One area that is lacking in the long-term studies is research surrounding weight maintenance. Only two studies (16, 19) have specifically looked at the effects artificial sweeteners have on weight maintenance in adults. One study only looked at the effects of aspartame, and therefore, the results cannot be generalized to the other artificial sweeteners. The other study required participants to abstain from artificial sweetened beverage intake and instead drink water only. This behavioral change is not typically required of the general population undergoing weight loss. Therefore, further studies to look at the effects all artificial sweeteners have on weight maintenance in participants more representative of the general population could be beneficial.

III. Epidemiological Studies

Although randomized controlled trials are considered the gold standard, most experimental research on this topic is limited to a twelve-month period. Therefore, other studies have examined how artificial sweeteners may affect weight in a longer time-frame. The

epidemiological studies done on this topic explored artificially-sweetened beverage intakes, BMI, and waist circumferences at baseline, and then took these measurements again three times over 9.4 years (8), six times over 8 years (7), or once at 8 years (6). The trends seen at baseline vs. the follow-up periods were analyzed.

A. Results from Epidemiological Studies

When comparing the groups of individuals who consumed artificially-sweetened beverages to the groups who did not, the change in BMI was greater (6, 7) as well as the change in waist-circumference (8). Those that consumed the greatest amount of artificially-sweetened beverages had the highest increases in waist-circumference, suggesting a dose-relationship. In addition, those who discontinued use of artificially-sweetened beverages by the follow-up had lower changes in BMI than those who continued use (6). These trends indicate a positive relationship between artificial sweeteners and weight gain.

B. Issues with Epidemiological Evidence

Although epidemiological studies are able to show trends, they cannot prove causation. For example, evidence from these studies (6-8) show a trend towards higher BMI and waist-circumference in individuals who consumed greater amounts of artificial-sweetened beverages. However, the results cannot prove that artificial sweeteners caused the higher anthropometrics. Although it is possible, it is also possible that those with higher BMI's consume more artificially-sweetened beverages in an attempt to decrease their weight, resulting in higher levels of overall consumption. In fact, the epidemiological study done by Fowler et al (6) found an association between artificial sweetener consumption and dieting (6), encouraging a view that the latter explanation may be the reasoning behind these findings.

IV. Conclusion

Obesity is rising and is expected to continue to rise (20). With the rise of artificial sweeteners being used in an attempt to combat the obesity epidemic, it is encouraging that a large amount of evidence suggests these sweeteners are not a contributor (9-18) including short-term and long-term trials studying free-living individuals as well as those on a weight-loss regimen. However, the rat studies (2-4) and epidemiological studies (6-8) suggesting otherwise cannot be ignored. Because there is still controversy surrounding this topic, further studies are needed to solidify the evidence.

Chapter 3: Methods

Overview

As stated previously, the purpose of the present study was to see if artificial sweetener consumption in foods and beverages could affect total weight loss and maintenance in adults on a weight-loss program. The study also aimed to examine whether or not the type of artificial sweetener consumed (aspartame, sucralose, acesulfame-K, or saccharin) had an effect on the amount of total weight loss. In order to study these objectives, a secondary analysis of previously collected data from a randomized, clinical trial (Phone versus Clinic; PVC) was done.

The primary aim of the initial clinical trial (PVC) was to determine if the amount of weight lost (over 6 months) and maintained (over 12 months) were equivalent in weight management programs utilizing phone counseling versus face-to-face counseling at a clinic. This thesis took the existing data from this study and analyzed it in a different way than originally intended. Because it was a secondary analysis, the initial study had already been approved by the human subjects committee #16529, the subjects had already been recruited, and data had already been collected.

Sample

The data used for the present study include 395 overweight/obese men and women. Inclusion criteria were: being between the ages of 18 and 65, having a BMI of 25 to 39.9 kg/m², and being able to obtain clearance for participation from their primary care physician. Those with chronic medical conditions (such as diabetes or hypertension, etc.) were allowed to participate as long as the condition was medically controlled and they had clearance from a physician. Exclusion criteria included: participation in a weight loss or physical activity study

within the previous 6 months, regular physical activity, weight gain or loss of 2.27 kg in the 3 months prior to screening, pregnancy or serious medical risk or eating disorder.

Participants were recruited over about 3.5 years using newspaper advertising, email list serves, public service messages, media contacts, word of mouth, and the waiting list participation in a separate study (University of Kansas Weight Control Research Project). They were randomized using stratified randomization by gender. Sixty-nine males and 132 females were randomized into the phone group, and 62 males and 132 females were randomized into the face-to-face clinic group.

Setting

The study was conducted in the KC metro area and Lawrence, KS.

Ethics

The study was approved by the KUMC Human Subjects Committee #16529. All participants signed informed consent prior to participation.

Procedures

Initial Study

Approved subjects were randomized into two groups: one that received group weight-loss counseling via phone and one that received group weight-loss counseling via a traditional in-person clinic. Each group then completed 6 months of weight loss followed by 12 months of weight maintenance. The format of the counseling given at the in-person clinic and the phone conference calls during weight-loss was identical. They were done in group sessions, and

included education on nutrition, physical activity, and lifestyle modification followed by a group discussion. The only difference between the groups was that those in the in-person group were weighed at the sessions, while weight was self-reported for the phone group.

Diets during the weight-loss phase for both groups were restricted to about 1200 to 1500 kcal per day. Participants were asked to consume pre-packaged meals, fruits and vegetables, and non-caloric beverages to fill most of these calories. They were asked to consume at least 3 low-calorie shakes (provided), 2 entrees (provided), and 5 (1-cup servings) of fruits or vegetables per day. During the weight maintenance phase, participants received a meal plan with suggested servings of grains, proteins, fruits, vegetables, dairy, and fat based on USDA guidelines (34). They were also encouraged to continue to consume at least 14 shakes and entrees, and 5 servings of fruits or vegetables, but were not required to do so.

Participants were not specifically required to consume artificial sweeteners during the study, nor was there a specific weight loss lesson regarding the use of artificial sweeteners. However, all participants were instructed to avoid sugar, and were only allowed to consume beverages with less than 5 calories per serving during the weight loss phase. Furthermore, the meal replacement shakes they were asked to consume contained artificial sweeteners. Therefore, it is likely that many of these sweeteners were consumed during the study.

Weight and 3-day diet records were taken at baseline, 6 months, 12 months, and 18 months. Weights were taken between 6 and 10 am, prior to breakfast, and after participants had attempted to void. All participants were required to wear a standard hospital gown during weighing. Diet records were done on two week days and one weekend. Each participant was mailed instructions on how to complete the record. Records were reviewed by research staff and clarification obtained if needed. The records were then entered into the Nutrition Data System

for Research (NDSR version 2007, University of Minnesota). The present study used the output from the 3-day food records as well as data on the weight of the participants at each time point.

A goal of 300 minutes per week of moderately vigorous physical activity (MVPA) was targeted. Participants reported minutes of MVPA in daily logs that were submitted twice a week during the weight loss phase and weekly during weight maintenance. The data were verified by a subsample of randomized participants wearing accelerometers.

Present Study

In order to answer the three research questions, two separate analyses were conducted. For the first analysis, which examined the effect that the amount and type of artificial sweetener had on the entire duration of the weight-loss regimen, baseline was defined as 0 months. For the second analysis, which looked specifically at the effect that artificial sweeteners have on the weight-maintenance period, baseline was defined as 6 months.

Research Question #1

Participants were first categorized into three groups based on the percentage of total weight lost, from month 0 to month 18. The categories chosen were <5% weight loss, 5-10% weight loss, and >10% weight loss. The total amount of artificial sweetener consumed, in mg, was then compared between the three groups.

Research Question #2

In addition to comparing the total amount of sweetener consumed, the amount of each specific sweetener (aspartame, sucralose, acesulfame-K, or saccharin), in mg, was compared between groups. The same percentage of total weight loss groups as to answer Research Question 1 were used for this analysis.

Research Question #3

The tertiary aim of the investigation was to assess the association of artificial sweetener intake and successful long-term weight loss maintenance. Therefore, only those participants who lost at least 5% of their body weight during the weight loss phase (baseline to 6 months) were included in this analysis. Participants were grouped by level of percent weight regain from month 6 to month 18, with group 1 representing the tertile with the highest amount of regain and group 3 representing the tertile with the lowest amount of regain. Characteristics for each group are presented in Table 2. The average weight change from month 6 to month 18 in the highest weight regain group (group 1) was approximately +11.0% whereas weight change for the lowest weight regain group (group 3) was approximately +0.4%.

Materials

Since the present study was a secondary analysis, no further materials were needed to complete the study except the database with the 3-day diet records and body weight and statistical analysis software.

Analysis of Data

Baseline demographics and outcome variables were summarized using descriptive statistics and bivariate tests –i.e., Analysis of variance (ANOVA) and chi-square test. ANOVA was conducted to compare energy intake (kcal/day), total artificial sweetener (mg/d), acesulfame k (mg/d), aspartame (mg/d), saccharin (mg/d), MVPA, and weight change (%) between groups. Then, mixed modeling was utilized to examine differences between groups (group effect), changes over time (time effect), and group-by-time interaction for each outcome variable,

accounting for the covariates including age, sex, energy intake, and MVPA. All analyses were conducted using SAS 9.4 (SAS Institute, 2002-2012).

Chapter 4: Results

The purpose of the present study was to see if total artificial sweetener consumption in foods and beverages affected total weight loss and maintenance in adults on a weight-loss program. In addition, the study aimed to answer whether or not the type of artificial sweetener consumed (aspartame, sucralose, acesulfame-K, or saccharin) affected total weight loss in these individuals.

Two separate analyses were conducted. The first examined artificial sweeteners impact on weight loss, and included all participants who were randomized to the diet intervention and completed food records, the second analysis examined sweeteners impact on weight maintenance and only included participants who had lost at least 5% of their baseline weight at month 6.

Subjects

Two hundred and eighty eight participants had valid food records at baseline and were therefore included in the weight loss analysis. On average, participants who lost <5% were 42.0 \pm 9.7 years of age, 72.1% female, and 25.4% minorities; participants who lost 5-10% were 45.4 \pm 9.1 years, 61.1% female, and 23.6% minorities; and participants who lost >10% were 47.8 \pm 8.8 years, 68.1% female, and 18.1% minorities. Participants who lost <5% had an average weight change of -0.1%, participants who lost 5-10% had an average weight change of -7.5%, and participants who lost greater than 10% had an average weight change of -16.9%. Of the participants who consumed artificial sweeteners, the majority (89%) came from beverages. Food contributed 10.6% and gum contributed 0.4%. Full baseline characteristics are presented in Table 1. Participants who lost <5% were significantly younger than participants who lost 5-10% ($p=0.035$) and those who lost >10% ($p<0.001$). There were no other significant baseline differences between participants who lost <5%, 5-10%, and >10% weight at 18 months.

Table 1: Baseline Characteristics-All Participants

Variable	<5% Weight Loss			5-<10% Weight Loss			>10% Weight Loss		
	N	MEAN	SD	N	MEAN	SD	N	MEAN	SD
Age (years)	122	42.0 ^a	9.7	72	45.4 ^b	9.1	94	47.8 ^c	8.8
Weight (pounds)	122	221.7	38.1	72	217.6	43.0	94	218.5	40.3
Height (inches)	122	66.5	3.4	72	67.3	4.1	94	66.7	3.65
BMI (kg/m ²)	122	35.2	4.9	72	33.6	4.8	94	34.2	4.2
Weight change from 0-18 months (%)	122	-0.1	3.5	72	-7.5	1.5	94	-16.9	6.1
Female (n,%)	88	72.1		44	61.1		64	68.1	
Race (n,%)									
White	91	74.6		55	76.4		77	81.9	
African American	23	18.9		11	15.3		14	14.9	
Asian	2	1.6		2	2.8		1	1.1	
Native Hawaiian or Pacific Islander	1	0.8		0	0.0		0	0	
American Indian or Alaskan Native	2	1.6		0	0.0		1	1.1	
Other/Unknown	2	1.6		3	4.2		1	1.1	
Multiracial	1	0.8		1	1.4		0	0	
Ethnicity (n,%)									
Hispanic or Latino	9	7.4		7	9.7		4	4.3	
Not Hispanic or Latino	90	73.8		50	69.4		79	84	
Unknown	23	18.9		15	20.8		11	11.7	

a is significantly different from b (p=0.035) and c (<0.0001)

Two hundred and sixty six participants lost at least 5% of their initial weight during the weight-loss phase and were included in weight-maintenance analysis. Participants were divided into tertiles based on their weight change from 6 months to 18 months. On average, participants in Tertile 1 were 48.2 ± 8.5 years, and 17.4% minorities; participants in Tertile 2 were 45.9 ± 8.7 years, 61.4% female, and 22.9% minorities; and participants in Tertile 3 were 42.9 ± 9.7 years of age, 71.2% female, and 21.1% minorities. Participants in Tertile 1 had an average weight change of +11.0%, participants in Tertile 2 had an average change of +5.8%, and participants in Tertile 3 had an average weight change of +0.4%. Full baseline characteristics for the second analysis are shown in Table 2.

Age, weight, height, BMI, gender, race, and ethnicity were compared between the groups. Age was significantly higher in Tertile 1 compared to Tertile 2 ($p=0.021$) and Tertile 3 ($p<0.0001$). Age was also significantly higher in Tertile 2 when compared to Tertile 3 ($p=0.001$). Height was significantly different between Tertile 2 and Tertile 3 ($p=0.015$). BMI was significantly different between all three tertiles (all $p<0.0001$).

Table 2: Baseline Characteristics-Participants Who Lost $\geq 5\%$ of Body Weight During Weight Loss Phase

Variable	Tertile 1 (Maintained Weight)			Tertile 2 (Regained <10%)			Tertile 3 (Regained >10%)		
	N	MEAN	SD	N	MEAN	SD	N	MEAN	SD
Age (years)	92	48.2 ^a	8.5	70	45.9 ^b	8.7	104	42.9 ^c	9.7
Weight (pounds)	92	219.9	39.6	70	217.9	43.6	104	223.2	38.2
Height (inches)	92	66.8	3.5	70	67.3 ^d	4.0	104	65.7 ^e	7.4
BMI (kg/m ²)	92	27.7 ^g	3.6	70	29.1 ^h	4.7	104	32.3 ⁱ	5.7
Weight change from 0-18 months (%)	82	+11	5.9	79	+5.8	5.5	78	+0.4	8.1
Female (n,%)	62	67.4		43	61.4		72	71.2	
Race (n,%)									
White	76	82.6		54	77.1		82	78.9	
African American	14	15.2		11	15.7		17	16.4	
Asian	1	1.1		2	2.9		2	1.9	
Native Hawaiian or Pacific Islander	0	0		0	0		1	1	
American Indian or Alaskan Native	1	1.1		0	0		1	0.9	
Other/Unknown	0	0		2	2.9		0	0	
Multiracial	0	0		1	1.4		1	1	
Ethnicity (n,%)									
Hispanic or Latino	4	4.4		6	8.6		7	6.7	
Not Hispanic or Latino	78	84.8		49	70.0		77	74.0	
Unknown	10	10.9		15	21.4		20	19.2	

a is significantly different from b (p=0.021) and c (p=<0.0001)
b is significantly different from c (p=0.001)
d is significantly different from e (p=0.015)
g, h, and i are significantly different from one another (all p=<0.0001)

When comparing participants who lost <5%, 5-10%, and >10% weight at 18 months, artificial sweetener intake at 6 months was significantly higher in the >10% weight loss group (553.9 ± 882.3) compared to the < 5% weight loss group (293.5 ± 560.4 ; $p = 0.033$). Artificial sweetener intake did not significantly differ between groups at any other time point ($p > 0.05$). Furthermore, the > 10% weight loss group had significantly higher MVPA than the < 5% weight loss group at all time points (6 months ($p=0.001$), 12 months ($p=0.002$), and 18 months ($p=0.001$)). The 5-<10% weight loss group had significantly higher physical activity than the <5% weight loss group at 12 months ($p=0.042$). Therefore, physical activity was controlled for in the mixed modeling analyses. Full data are presented in Table 3.

Mixed modeling results revealed no significant group ($p = 0.686$), time ($p=0.141$), or group*time interaction ($p=0.267$) over the 18 month study period. There was no significant effect of sex, energy intake, or MVPA on total artificial sweetener intake. Older age was significantly related to higher total artificial sweetener intake ($p = 0.044$).

Sucralose intake was significantly higher at 6 months in the >10% weight loss group (376.0 ± 840.6) compared to the <5% weight loss group (142.9 ± 521.8 ; $p=0.049$). There were no differences in intake of the other artificial sweeteners between those who lost <5%, 5-10%, and >10% weight at 18 months.

Mixed modeling was used to compare group differences over time regarding specific artificial sweetener intake. Acesulfame-K significantly increased throughout the 18 month intervention ($p=0.020$). There was no significant group ($p=0.980$) or group*time interaction ($p=0.851$) in this change. No significant group, time, or group*time interactions were seen regarding sucralose ($p=0.576, 0.309, 0.112$, respectively), aspartame ($p= 0.301, 0.113, 0.407$, respectively), or saccharin ($p=0.667, 0.523, 0.926$, respectively). Higher aspartame intake was

significantly associated with increased MVPA ($p=0.008$). Higher saccharin intake was significantly associated with increased energy intake ($p=0.017$).

When examining artificial sweetener intake on weight maintenance, total artificial sweetener intake did not differ between the groups at any time point ($p>0.05$). Tertile 3 had significantly higher levels of MVPA (39.5 ± 22.0) than in Tertile 1 (25.8 ± 21.5 ; $p=0.034$) at 18 months, and this was therefore controlled for in further analyses. Complete data for energy intake, sweetener intake, and MVPA are presented in Table 4.

Group differences over time were compared between the groups using mixed modeling. No significant group ($p=0.801$), time ($p=0.148$), or group*time ($p=0.600$) interactions were observed. Higher energy intake and higher physical activity was significantly associated with higher artificial sweetener intake ($p=0.001$, 0.032 , respectively).

Table 3: Artificial Sweetener Impact on Weight Loss

	< 5% Weight loss			5 - < 10% Weight Loss			> 10% Weight Loss		
	N	MEAN	SD	N	MEAN	SD	N	MEAN	SD
Energy Intake (kcal/day)									
<i>Baseline</i>	117	2242.6	652.8	72	2250.3	633.1	91	2294.5	630.6
<i>6 months</i>	95	1527.7	413.1	65	1433.9	364.1	88	1473.4	341.7
<i>12 months</i>	72	1688.8	441.6	55	1603.9	485.6	83	1621.7	450.0
<i>18 months</i>	95	1751.7	526.4	65	1684.9	458.9	84	1663.5	477.3
Total Artificial Sweetener (mg/d)									
<i>Baseline</i>	117	245.8	484.7	72	498.0	1289.6	91	325.3	556.5
<i>6 months</i>	95	293.5 ^a	560.4	65	405.9	586.1	88	553.9 ^c	882.3
<i>12 months</i>	72	383.8	912.4	55	565.2	977.8	83	539.8	979.5
<i>18 months</i>	95	347.0	697.6	65	589.6	1047.3	84	618.5	1052.2
Acesulfame k (mg/d)									
<i>Baseline</i>	117	6.2	15.5	72	4.3	8.7	91	8.2	24.3
<i>6 months</i>	95	7.3	19.7	65	6.0	15.0	88	10.3	22.8
<i>12 months</i>	72	10.5	26.2	55	7.3	23.1	83	14.5	39.6
<i>18 months</i>	95	6.9	21.5	65	4.4	13.3	84	19.1	73.3
Aspartame (mg/d)									
<i>Baseline</i>	117	109.1	176.7	72	157.1	244.1	91	169.1	331.7
<i>6 months</i>	95	138.8	211.9	65	153.7	206.3	88	163.0	265.2
<i>12 months</i>	72	133.7	204.0	55	225.2	408.6	83	170.6	257.0
<i>18 months</i>	95	133.8	214.9	65	156.5	221.7	84	171.3	262.4
Saccharin (mg/d)									
<i>Baseline</i>	117	9.0	23.5	72	11.3	43.7	91	9.0	34.1
<i>6 months</i>	95	4.6	14.2	65	3.5	13.3	88	4.5	15.6
<i>12 months</i>	72	5.3	15.6	55	3.3	14.6	83	3.5	18.3
<i>18 months</i>	95	4.0	15.2	65	8.8	24.7	84	5.6	22.0
Sucralose (mg/d)									
<i>Baseline</i>	117	122.4	460.8	72	325.3	1291.6	91	139.1	464.4
<i>6 months</i>	95	142.9 ^d	521.8	65	242.6	578.3	88	376.0 ^f	840.6
<i>12 months</i>	72	234.3	901.5	55	329.4	874.9	83	351.2	974.9
<i>18 months</i>	95	202.3	690.8	65	419.9	1024.6	84	422.6	1024.4
MVPA									
<i>Baseline</i>	76	16.9	14.5	34	17.4	14.4	58	16.5	14.6
<i>6 months</i>	45	26.0 ^g	15.7	29	36.6	19.0	49	42.3 ⁱ	26.5
<i>12 months</i>	29	17.2 ^j	14.1	18	31.1 ^k	19.1	41	33.7 ^m	21.4
<i>18 months</i>	32	20.1	18.4	16	28.0	18.2	39	38.4 ^o	21.6

c is significantly different from a (p=0.033)

f is significantly different from d (p=0.049)

g is significantly different from i (p=0.001), m (p=0.002), and o (p=0.001)

k is significantly different from j (p=0.042)

Table 4: Artificial Sweetener Impact on Weight Maintenance

	Tertile 1 (Maintained Weight)			Tertile 2 (Regained <10%)			Tertile 3 (Regained >10%)		
	<i>N</i>	MEAN	<i>SD</i>	<i>N</i>	MEAN	<i>SD</i>	<i>N</i>	MEAN	<i>SD</i>
Energy Intake (kcal/d)									
<i>6 Month</i>	76	1528.9	379.4	75	1424.6	360.0	74	1476.0	347.7
<i>18 Month</i>	71	1845.6	626.0	67	1635.2	450.4	70	1665.4	460.4
Total Artificial Sweeteners (mg/d)									
<i>6 Month</i>	76	431.8	642.7	75	342.8	538.4	74	449.6	797.1
<i>18 Month</i>	71	398.8	568.8	67	477.5	853.7	70	725.2	1345.6
MVPA									
<i>6 Month</i>	45	33.6	20.2	30	34.6	21.5	38	41.1	25.0
<i>18 Month</i>	32	25.8 ^a	21.5	21	26.7	18.0	28	39.5 ^c	22.0

a is significantly different from c (p=0.034)

Chapter 5: Discussion

Among overweight men and women undergoing a 6 month weight-loss regimen followed by a 12 month weight maintenance period, the amount of artificial sweetener consumed did not differ over time between individuals who lost >10% of their body weight, individuals who lost 5-10%, and individuals who lost <5%. Although the associations found in the present study differ from studies conducted previously, similar conclusions can be made.

Previously, two research studies by Peters et al and Blackburn et al examined the effects of artificial sweeteners over the duration of a weight-loss regimen and subsequent maintenance period (16, 19). In both studies, those consuming artificial sweeteners had greater success in total weight loss than those discouraged their use, and the authors concluded that sweeteners may aid in weight loss. The present study found no such associations. However, regardless of the amount of sweetener consumed, all three groups, on average, had a negative % weight change from baseline to 18 months, thereby showing that sweeteners did not prevent weight loss.

Raben et al, Tate et al, and Tordoff et al found that both adding artificial sweeteners to the diet (14, 18) and replacing sugar-sweetened products with artificially-sweetened products (15) were advantageous in weight-loss efforts. Participants in the present study were not required to add or replace products with artificial sweeteners, but they were encouraged to decrease added sugar intake. Furthermore, the meal replacement shakes they were required to consume during the initial six month weight loss phase contained artificial sweeteners. It is therefore likely that additional artificial sweeteners were added to the diet, and that sugar-sweetened products were replaced with artificially-sweetened ones. Despite this similarity in studies, the present study did not find the same associations as Raben, Tate, and Tordoff.

The differences found between previous studies and the present study cannot be determined from these data. However, it can be speculated that it may be due to the differences in behavioral change between the subjects in the studies. For example, in the Peters and Blackburn studies, the subjects were specifically assigned to either consume or not consume artificial sweeteners. The group that was discouraged from using sweeteners could have craved a sweet beverage, seeking out a calorically dense alternative, which could have led to a greater difference in weight loss between the groups.

Similarly, in the studies done by Raben, Tate, and Tordoff, although participants were not partaking in a weight-loss program, they were still instructed if/when to add or replace products with artificial sweeteners. None of the participants in the present study were specifically asked to do so. Therefore, although artificial sweetener consumption may have increased from baseline in an attempt at weight loss (as was seen with acesulfame-k intake), there could have been a difference in behavioral change between the studies, explaining the differences in associations found. Furthermore, because participants in the present study were not required to add or replace products, they more appropriately represent the typical population attempting weight loss.

Results also showed that those who lost the greatest amount of weight throughout the study consumed higher amounts of total artificial sweeteners and sucralose at the end of the weight loss phase (6 months). Blackburn et al (16) found similar results regarding both a weight loss phase and a weight maintenance phase, and concluded that sweeteners may have a dosage relationship.

Unlike Blackburn's results, the association in the present study was not significant when compared over time, and was not seen at any other time point. Furthermore, it has been found that individuals tend to consume more artificial sweeteners when attempting to lower calories

and lose weight, which could explain why consumption was highest at the end of the weight loss phase. Regardless, the results call for further research to explore the validity and mechanism behind this association.

In an attempt to limit calories, those attempting to lose or maintain weight often lean towards consuming more artificial sweeteners (35). The results of this study are therefore encouraging. Unlike rat studies (2-5) and prospective cohort studies (6-8), which suggest that artificial sweeteners may lead to weight gain and therefore cannot be used successfully in weight loss efforts, the current results show the opposite. Although artificial sweeteners did not appear to lead to greater weight loss as some studies have found (14-19), the addition of them in the diet did not hinder weight loss efforts either. Therefore, they can successfully be used in conjunction with a weight loss regimen to promote weight loss.

Type of artificial sweetener intake did not differ between those who lost >10% of their weight, those who lost 5-10%, and those who lost <5%. This is a significant finding, as to my knowledge, this is the first study to examine the effect of specific multiple artificial sweeteners on weight loss in humans. Blackburn et al studied aspartame supplementation over the course of a weight loss and maintenance regimen. However, it did not compare any of the other most common sweeteners (sucralose, acesulfame-k, or saccharin).

Saccharin is specifically of interest, as multiple rat studies have found that this sweetener leads to increased energy intake and weight gain (2-5). The present study supports these energy intake findings, discovering that when adjusting for energy intake as a covariate, increased saccharin intake was associated with increased energy intake. While the mechanism behind this finding cannot be explained, it should be noted that the increased energy intake seen in the

present study did not lead to a difference in weight lost between the groups. Therefore, it can be speculated that the type of sweetener consumed did not affect the amount of weight lost.

Each specific sweetener has a different level of sweetness (36) and slightly different taste/use. For example, saccharin has been reported to have a bitter aftertaste (37), while sucralose is heat-stable so it can be used in cooking (38). The results from the present study are encouraging for those who have a desire to lose weight, but prefer or use one sweetener over another. Each type of sweetener is equal in their ability to be used without adverse effects to weight loss.

Those who lost at least 5% of their initial weight were considered to have made it to the weight maintenance phase of the program. Of these participants, total artificial sweetener intake did not differ between any of the groups. Similar to the analysis of weight loss from baseline to 18 months, the results seen regarding weight maintenance and artificial sweeteners didn't reflect the results from Blackburn (16) and Peters (19), who found that artificial sweetener intake led to less weight regain. Despite this, artificial sweetener intake does not appear to be associated with weight regain after a weight-loss phase, and can therefore be used successfully as part of a weight maintenance regimen.

Similar to saccharin intake, total artificial sweetener intake was significantly associated with higher energy intake. These results support those found in rats (2-5). Unlike the rat studies, however, the increased energy intake seen in the participants of the present study did not lead to greater weight regain.

Typically, the weight loss phase of a weight management program lasts a finite amount of time. For example, during the Blackburn (16) and Peters (19) studies, the weight loss phase lasted only 12 weeks while the weight maintenance phase continued for another 9 months and 12

months, respectively. Weight maintenance is therefore arguably the longer period of one's life. Artificial sweetener use does not appear to lead to greater regain during this period, which is encouraging for artificial sweetener use.

Limitations

There are several limitations to the present study. It was a secondary analysis using previously collected data. Therefore, the information available was limited, and there was no opportunity for further clarification of dietary records, weights, etc. In addition, the dietary intake data were self-reported which are known to have flaws such as underreporting of energy intake. There were coding rules used when entering the diet records into NDSR, and quality assurance methods used to check the records. Despite this, there could still have been human errors in the data entry. Collected data are only as reliable as the individuals who entered the dietary records, and therefore errors in the data are possible.

Limitations to the study reach past data entry as well. For example, the primary purpose of the initial study was not to examine artificial sweeteners. Therefore, those collecting the diet information may not have probed for specific type of artificial sweeteners. Since part of my analysis looks at the association between weight lost and specific artificial sweeteners, this fact could have affected the result. Finally, the initial study was analyzed in 2007, before the non-nutritive sweetener Stevia was popularized, and therefore does not include this sweetener or any others discovered after 2007.

Chapter 6: Summary

Previous studies have had conflicting results regarding artificial sweeteners and body weight. Prospective cohorts (6-8) and rat studies (2-5) have suggested that artificial sweeteners may lead to increased consumption and subsequent weight gain. On the other hand, randomized controlled trials using human subjects have suggested the opposite (9-19). In addition to these conflicting results, there are only two studies (16, 19) that have specifically evaluated the effects artificial sweeteners may have on weight maintenance. The study done by Blackburn et al. (16) was conducted in 1997 and therefore may not be generalizable to populations today. In addition, Peters et al. (19) results may have been skewed by behavioral change differences between the study groups.

The present study hopefully filled the gaps of previous research by specifically looking at those undergoing a weight loss regimen and subsequent weight maintenance phase who were not required to make a behavioral change regarding artificial sweetener intake. In addition, it is the first, to my knowledge, to study a population participating in a randomized controlled trial that had not previously been required to consume artificial sweeteners while completing the weight-loss regimen. Therefore, the sample is more representative of those attempting to lose weight and the results can be generalized to a broader population.

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APPENDIX A: Foods and Beverages Consumed with Artificial Sweeteners

Aspartame	Sucralose	Saccharin	Acesulfame-K
<u>Beverages:</u> Diet Coke Coke Zero Diet Mr. Pibb Diet A&W Diet Dr. Pepper Diet 7-up Diet Sunkist Diet Mountain Dew Diet Pepsi Fresca Sugar Free Snapple Sugar Free Lemonade Sugar Free Tea Slim Fast Sugar Free Hot Cocoa Sugar Free Red Bull HMR Shake <u>Food:</u> Sugar Free Jello Fiber One Cereal Sugar Free Ice Cream Light Yogurt Sugar Free Popsicles Sugar Free Juice Sugar Free Jelly/Jam Sugar Free Pudding <u>Other:</u> Sugar Free Gum Equal Packets	<u>Beverages:</u> Diet 7-up Diet Mountain Dew Diet Shasta <u>Food:</u> Fiber One Cereal Sugar Free Vanilla Wafers Sugar Free Pudding Sugar Free Ice Cream Bars Sugar Free Fudge Bars Sugar Free Pancake Syrup Sugar Free Yogurt Walden Farms Salad Dressing <u>Other:</u> Splenda Packet	<u>Beverages:</u> Diet Coke Diet Mountain Dew Diet Pepsi Diet Tonic Water Sprite Zero Sugar Free Juice <u>Other:</u> Sweet' N Low Packet	<u>Beverages:</u> Diet Coke Coke Zero Fresca Diet Mr. Pibb Diet Sprite Diet A&W Diet Mountain Dew Diet Pepsi Diet Sierra Mist Diet Sunkist Sugar Free Lemonade Sugar Free Tea HMR shake Sugar Free Red Bull <u>Food:</u> Sugar Free Pudding Sugar Free Jello Quaker Rice Cakes Sugar Free Vanilla Wafers Sugar Free Ice Cream Bars Sugar Free Fudge Bars Yoplait Yogurt <u>Other:</u> Sugar Free Gum